PATENT SPECIFICATION 1,190,459

DRAWINGS ATTACHED.

1,190,459

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COMPLETE SPECIFICATION.

A Circuit Arrangement for Automatically Tuning a Communication Apparatus.

We, GENERAL DYNAMICS CORPORATION, a Corporation organized under the laws of the State of Delaware, United States of America, of One Rockefeller Plaza, New York 20, State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to circuit arrangements for automatically tuning communications apparatus. The invention is especially suitable for use in radio apparatus having electronically tuned circuits which are to be tuned to a desired frequency as dictated by the frequency of a reference signal.

Heretofore, tuning of radio apparatus has been accomplished by synchronizing a variable frequency oscillator with a reference frequency through the use of a phase locked-loop. Amplifier circuits in the radio were also tuned by means of a control voltage generated in the phase locked-loop. Such tuning of the radio apparatus has not been entirely automatic and has required the aid of mechanically or manually operated devices for switching in different tuned circuit elements. Tuning elements used in variable frequency oscillators and tuned amplifiers (e.g. voltage variable capacitors) are limited in tuning range. In other words, a tuned circuit containing voltage variable capacitors may only be tuned over a limited band of frequencies. The band of frequencies over which such tuned circuits are operative is also a function of the cost of the voltage variable capacitors used therein. Accordingly, it is desirable that an automatically tuned radio be capable of operating in different bands in order to cover a wide range of frequencies without the need for mechanical band switching means. The need for mechanically or electro-mechanically operative switches, manually operative components or complex switching logic to change bands, has imposed serious drawbacks an automatically tuned radio apparatus.

Therefore, the invention is intended to provide communication apparatus which is automatically tunable in a wide range of frequencies, whereby any specific frequency within such wide range is determined by the frequency of a reference signal and the tuning is accomplished without mechanical switching or manually controlled devices.

The above aim has been accomplished in a circuit arrangement for automatically tuning with the aid of a reference frequency signal, a communications apparatus having at least one tuned circuit, which according to the invention is characterized in that, a phase locked frequency control loop comprises at least one variable frequency oscillator including said tuned circuit which is connected with its output to one input of a comparing circuit the other input of which is connected to a source supplying said reference frequency signal, the output of the comparing circuit being connected to a tuning voltage generator which generates a tuning voltage varying in magnitude at a rate determined by the difference in frequency between the reference frequency signal and the variable frequency signal from said oscillator, said tuning voltage generator being connected with its output to said tuned circuit and to the input of the variable frequency oscillator.

[*Price* 5*s*. 0*d*.]

It is an advantage of the present invention that circuits employing the invention are substantially immune to internal frequency drift producing effects.

It is yet another advantage of the invention that it is suitable for generating signals for injection into a mixer circuit to generate a constant intermediate frequency which is, automatically, a signal of greater purity than the reference signals from which the intermediate frequency is produced.

In order that the invention may be clearly understood, it will now be described, by way of example, with reference to the accompanying drawings in which:

Fig. 1 is a block diagram of a receiver employing an automatic tuning system in accordance with the invention;

Fig. 2 is a more detailed block diagram of the automatic tuning system shown in Fig. 1;

Fig. 3 is a more detailed diagram of the coarse tuning voltage generator which is shown in Figs. 1 and 2; and

Fig. 4 is a more detailed diagram of the variable frequency oscillators and their associated band switch also shown in Fig. 2.

Referring to Fig. 1, there is shown a receiver which is connected to an antenna 10. The RF signals which are picked up by the antenna are transmitted through a voltage controlled attenuator circuit 12 to radio frequency amplifier circuits 14. The voltage controlled attenuator 12 may, for example, be a diode attenuator or a transistor attenuator which causes a signal loss depending upon the magnitude of a control voltage applied thereto. This control voltage may be derived from the intermediate frequency circuits of the receiver by automatic gain control circuits. Inasmuch as such circuits may be designed in accordance with known techniques, they and their connection to the voltage controlled attenuation 12 are not shown, in order to simplify the illustration. In addition, the voltage controlled attenuator receives a signal from a lock sensor circuit 18 which effectively squelches the input to the receiver from the antenna 10 until the receiver is tuned to the desired frequency.

The RF amplifier 14 is illustrated as having two channels 16 and 18 which are respectively allocated to different ones of two frequency bands, namely band A and band B. While only two channels are illustrated, it will be appreciated that the amplifier may have a larger number of channels, each allocated to a successive frequency band. In other words, band A may extend from 2 mc/s to 3 mc/s. Band B may extend from 3 mc/s to 4 mc/s, and so forth. The bandwidth of the various bands is determined by the choice of voltage variable capacitors used and the maximum and minimum frequencies in each band f max/f min may have a fixed ratio. The channel 16 includes a pair of voltage controlled tuned circuits 20 and 22, both tuned to Band A, which are connected to opposite sides of a radio frequency amplifier 24. The voltage controlled tuned circuits may be double tuned circuits containing a pair of coils and a pair of capacitors. The capacitors are voltage variable capacitors. By varying the tuning voltage applied to these capacitors over a tuning voltage buss 26, the circuit may be tuned continuously over the entire band A. The radio frequency amplifier 24 may be a single or multiple transistor amplifier which is tuned to the frequency to be received by means of the circuits 20 and 22. Additional stages of radio frequency amplification similar to the amplifier 24 may be provided in the channel 16.

CLAIM 4

The other channel 18 of the RF amplifier also contains a pair of voltage controlled tuned circuits 28 and 30. These circuits, however, are tuned to band B and may be tuned across band B by the tuning voltage which is applied to the buss 26. An RF amplifier 32, similar to the amplifier 24 is also connected between the tuned circuits 28 and 30.

The channels are selected by electronic band switches 34 and 36 which are connected to the input and output terminals thereof. These band switches may be diode switches of the type to be described hereinafter in connection with Fig. 4. In the event that more than two channels are utilized, a plurality of gate circuits may be employed for electronic band switching purposes. A band switching signal, which may be a voltage level, is generated by a band selection voltage generator circuit 38, such as a transistor amplifier which has different output levels when in conductive and non-conductive states. A turn-on voltage sensor 40, such as a resistance-capacitance circuit, may be connected to the power supply. Thus, when the power supply is connected to the receiver (viz. when the receiver is turned on), a signal is applied to the generator 38 causing it to saturate in one state, thereby providing a voltage level, say a positive polarity $+V_1$ to the band switches 34 and 38, and thereby initially selecting the first band, band A, by connecting channel 16 to the remainder of the receiver.

The band selection voltage generator 38 also receives a control voltage along buss 42 which causes it to switch to the opposite state, thereby providing a different voltage level, say of negative polarity $-V_2$, to the band switches 34 and 36 so that the other channel 18 is selected. Then, the receiver may be tuned through band B. In the event that additional channels tuned to

other successive bands are used, the band selection voltage generator 38 may include a counter which is stepped through its counting cycle by successive pulses which appear on the line 42. The counter will translate its count into a code which will operate logic gating circuits in the band switch 34 to select successive bands in the amplifier 14. The turn-on voltage sensor may, for example, be connected to the reset terminal of the counter so that when the receiver is turned on, the band A channel is connected initially.

The output of RF amplifier 14 is connected through the output band switch 36 to a mixer 44. The mixer also receives an injection signal from a phase locked-loop 46. The phase locked-loop is automatically tuned to the proper frequency for the signal to be received. This tuning is accomplished automatically, as will be described in detail hereinafter. The received signal is translated in frequency to the desired intermediate frequency which is selected by the intermediate frequency circuit 17. The latter circuits are connected to utilization circuits 48 which may, for example, include demodulation circuits of various types (viz. AM, FM, PM, FSK, and the like). Of course, if single sideband signals are received, requisite filtering may be included in mode selection circuits (not shown) which cooperate with the IF circuits.

claim 12

The phase locked-loop 46 provides tuning voltages for tuning the receiver. Thus, tuning voltages are generated in a fine tuning voltage generator 50 and in a coarse tuning voltage generator 52, both of which are connected in the phase locked-loop. The phase locked-loop also contains variable frequency oscillators 54 and 56 for band A and band B, respectively. These oscillators may be tuned through their respective bands by the tuning voltages which are generated in the fine and coarse tuning voltage generators 50 and 52 and applied thereto. The buss 26 is connected to the output of the tuning generators 50 and 52 and applies the tuning voltage to the voltage controlled tuned circuits 20, 22, 28 and 30 in the RF amplifier 14. Only one of the VFOs 54 and 56 is connected in the loop 46 at any one time by means of an electronic band switch 58. The switch 58 may be simlar to the switches 34 and 36. In the event that additional bands are utilized, additional VFOs corresponding thereto, which can be tuned through each of such bands, may be provided. The desired VFO and the desired RF amplifier channel are conjointly selected by control voltages applied to the switches 34, 36, and 58 by the band selection voltage generator 38.

The selected VFO provides the mixer selection signal which is applied to the mixer 44 by way of a buffer amplifier 60.

The selected VFO output is also circulated around the phase locked-loop through another amplifier 62. The loop is closed through a phase detector 64, the output of which is connected to the tuning voltage generators 50 and 52 through another buffer amplifier 66.

The receiver is tuned by means of a reference signal which may be obtained from a frequency synthesizer and is applied to an input of the phase detector 64. This reference signal may be of any frequency within the band over which the receiver is operative. The reference signal should, however, be offset from the frequency to which the receiver is to be tuned by the IF frequency, in accordance with superheterodyne techniques. The coarse tuning voltage generator responds to outputs of the phase detector which indicates that the reference signal is outside of the capture range of the phase locked-loop. It produces a tuning voltage which varies in amplitude in accordance with the difference in frequency between the reference signal frequency and the selected VFO output frequency. In the event that the maximum value of the coarse tuning voltage does not bring the selected VFO within the locking range of the loop, the coarse tuning control generator produces a control signal along line 42 which operates the band selection voltage generator and causes a band switching operation. The coarse tuning voltage then again increases in amplitude (viz. recycles) until the reference signal is within the capture range of the loop. At that time, the fine tuning voltage generator produces a fine (varying DC) tuning voltage which brings the loop into locked condition. Simultaneously, the RF amplifier is tuned to the desired frequency. When the receiver is locked, the coarse tuning voltage generator operates the lock sensor circuit 18 to permit the received signal to enter the receiver. Inasmuch as the phase locked-loop is an effective filtering device, it is tolerant of distortion of the reference signal, and does not lock to spurious frequency components of the reference signal. Moreover, the phase locked-loop continuously adjusts, say in the presence of drift due to temperature effects and the like, so that the receiver remains tuned to receive the desired frequency.

The phase locked-loop 46 is shown in greater detail in Fig. 2. The phase detector 64 is desirably a double balanced phase detector; i.e., both the reference signal and the VFO output signals are balanced out in the circuit, and only the modulation products $(f_r + f_v)$ and $(f_r - f_v)$ appear, where f_r is the reference frequency and f_v is the

VFO frequency. The low pass filter 68 passes only the difference frequency (f_r — f_v) and applies it to an amplifier 66. The amplifier 66 is desirably an operational amplifier having the proper feedback connected between its output and its input to provide a preset time constant Δ T which provides filtering action in the loop, thereby preventing high frequency transients from interfering with proper loop operation. In the event that the VFO output which is applied to the phase detector 64 is outside of the locking range of the loop, for instance where the difference frequency is more than a few cycles per second, an alternating current signal passes through the filter 68 and is applied to the circuits of the coarse tuning generator 52. This latter signal may be referred to as an error signal. The error signal is a slowly varying DC voltage when the difference frequency is within a few cycles. This DC voltage is generated as the fine tuning voltage and is passed through amplifier 66 and driver amplifiers 70 which are wide band amplifiers also capable of passing DC signals. Thus, the circuitry from the output of the phase detector 64 through the driver amplifiers 70 provides the fine tuning voltage generator 50. The driver amplifiers 70 also combine the output of the coarse tuning voltage generator 52 with the fine tuning voltage and apply them together to the VFOs 54 and 56 as well as to the buss 26. The VFOs 54 and 56 will be described in greater detail in connection with Fig. 4. Briefly, they contain voltage variable capacitors, the capacitance presented by which is varied in accordance with the amplitude of the tuning voltage. The tuning voltage may vary by as much as 100 volts in the illustrated system. As mentioned above, however, the number of bands utilized depends upon the tuning range of the voltage variable capacitors. This tuning range generally depends upon the voltage which these capacitors are capable of handling, at least as regards voltage variable capacitors which are presently available. Thus, the number of bands and the range of tuning voltage amplitude are related to each other. The system admits the use of many bands, and thus permits the use of low cost available voltage variable capacitors.

The error voltage is applied to a pulse shaper and amplifier circuit 72 in the coarse tuning voltage generator 52. This circuit may, for example, include an amplifier stage, a differentiator circuit, and a threshold detector connected in the order stated, which in effect, constitutes a positive crossover detector and provides a pulse for each cycle of the difference frequency component of the error voltage. In order to prevent introduction of any unwanted signals, a level sensing circuit may be used, for example, a reversely biased diode switch which prevents the amplifier from operating when signals are below a certain level. These pulses are applied to a variable frequency clock circuit 74. This circuit may be a flip-flop which is synchronized by the pulses but which can not provide output pulses at a rate which exceeds a certain rate consistent with the locking speed of the loop and the counting capacity of a counter in the staircase voltage generator 76 to which the output of the block pulse generator is connected. The last mentioned counter may be a binary counter having a plurality of successive flip-flops which enables the connection of a voltage source to a ladder network in accordance with the count stored therein. The ladder network produces a staircase voltage which is amplified to the desired level by means of the driver amplifiers 70. As the difference frequency component of the error voltage becomes smaller, the duration or width of the steps in the staircase increases. Accordingly, the tuning voltage permits the selected variable frequency oscillator, either 54 or 56, to approach the reference frequency at a decreasing rate. This feature effectively reduces the inertia in the coarse tuning circuits and precludes "overshoot". Thus, the phase locked-loop gradually approaches its locking range and readily locks to the desired frequency.

The capacity of the counter is, however, limited to a count which will result in a voltage which tunes the selected VFO to a frequency near the upper end of its band. This frequency desirably overlaps the frequency at the lower end of the next band. In other words, band A may end at 3 mc/s and band B may start at 2.7 mc/s. When the maximum count is reached, which in the illustrated case is 8,192 (2^{13} = 8,192; counter with 13 stages), the counter applies a pulse to the band sensing circuits 78. These circuits, in turn, apply a control voltage to the band selection voltage generator 38 which effects a band switching operation. Once the next band is selected, another cycle of staircase voltage is produced which should bring the phase locked-loop 46 into lock with the reference signal. In the event that only two bands are used (viz. band A and band B, as illustrated), the reference signal should lie within those bands. Additional bands may be provided, as mentioned above.

The coarse tuning voltage generator 52 is illustrated in greater detail in Fig. 3. The error voltage is applied to the pulse amplifier which provides a train of pulses of varying frequency in the event that (f_r — f_v), the difference frequency component, ex-

ists. This train of pulses is applied to the lock sensor circuit 18 which is a peak detector circuit containing a diode 80 and an RC filter 82. This circuit may be connected to a DC amplifier and thence to the voltage controlled attenuator 12 (Fig. 1) so as to squelch the input signal to the receiver before the receiver is tuned. Of course, when the receiver is tuned, the difference frequency component disappears and the squelch voltage generated by the circuit 18 is not effective.

The pulse train is applied to the variable frequency clock 74 which contains a triggerable flip-flop 84. Only the "0" output of flip-flop 84 (viz. the output which is at B+ potential when the flip-flop is reset and at ground potential when the flip-flop is set), is used. The "0" output of flip-flop 84 is connected to a charging circuit including a resistor 86 and a capacitor 88. The base of a transistor 90 is connected to the junction of this resistor and capacitor. The collector of this transistor is connected to the reset terminal of the flip-flop 84. The charging circuit and the transistor 90 assure that the flip-flop 84 will not exceed a certain maximum switching rate, for example 200 kc/s, and will produce an output pulse rate within the counting rate capability of the staircase generator 76, as well as the dynamic response range of the phase locked-loop. This frequency limitation results since the capacitor will not charge to a sufficient voltage to trigger the transistor and therefore inhibits the flip-flop switching rate if it exceeds 200 kc. In other words if the flip-flop switching rate is below 200 kc, the capacitor 88 can charge sufficiently through the flip-flop to reach a charge sufficient to trigger the transistor 90. This grounds the reset terminal allowing proper flip-flop action. However, if the flip-flop switching rate is high, the capacitor 88 does not have sufficient time to charge and the transistor 90 will not be triggered. The "0" output of flip-flop 84 is applied to the counter 76, and since the flip-flop is a "divide by 2" device, pulses at a 100 kc rate will be applied to the counter 76. The counter is a binary counter made up of thirteen flip-flop stages, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114 and 116. These stages are connected in tandem, with the "0" output of the preceding stage connected to the trigger input of the succeeding stage. The counter cooperates with a ladder network made up of thirteen resistors and a load resistor 118. The thirteen resistors are indicated by the legends $2^{\circ}n + 2^{12}n$. Alternate pulses applied to the trigger input T of each flip-flop will connect its output 0 to the voltage source at +B. This voltage source will then be connected to the resistor of the ladder network connected to the flip-flop output. The ladder network resistors and the load resistor 118 constiute a voltage divider with the output voltage thereof taken across the output load resistor 118. Accordingly, as the pulses are applied to the input of the first flip-flop 92 (the trigger inputs responding in the case of these flip-flops only to the negative going portion of the pulse), a successive step of the staircase voltage will appear across the output resistor 118. The duration of each step will depend upon the triggering pulse rate. Accordingly, as the triggering pulse rate decreases with a decreasing difference frequency component of the error voltage, the steps of the staircase will become wider. This permits the phase locked-loop to slowly approach locked conditon. In other words, the condition where the fine tuning voltage can lock the loop is reached at a decreasing rate. This permits 'capture" of the loop by the reference voltage without "overshoot" and more rapid acquisition of the reference signal.

When the maximum count is reached, (viz. 8,192), the last flip-flop 116 produces an output pulse which triggers a flip-flop 120. The flip-flop 120 provides the band sensing circuit 78 and produces an output voltage level of either $+V_s$ or O which is applied to the band selection voltage generator 38. When this voltage is positive (viz. when the flip-flop 120 is set, the receiver is conditioned to operate in band A, however, when the output of flip-flop 116 is $+V_s$, the receiver is conditioned to operate in band B). The effectiveness of the opposite polarity switching voltages generated in the band selection voltage generator 38 in selecting the different bands will be more apparent from Fig. 4 where it is shown how a diode electronic band switch responds to such opposite polarity levels to select either band A or B. When the second band, for instance band B, is selected, the counter starts a new cycle and will produce a staircase voltage which will tune the receiver to a frequency within band B.

The band A and band B variable frequency oscillators 54 and 56 are shown in Fig. 4. The band A oscillator 54 includes an amplifier 122 which is connected in Hartley configuration with a tuned circuit 124. The tuned circuit also includes a pair of voltage variable capacitor diodes 126 to which the tuning voltage is applied by way of a resistor 128. The band B variable frequency oscillator is identical except that the inductor in its tank circuit is of a different value of inductance than the inductor 124 of the band A oscillator 54 so that the band B oscillator may operate in the higher

frequency band. The output taps 130 and 132 of the oscillators 54 and 56 are connected through diodes 134 and 136 and through a capacitor 138 to the oscillator output which in turn is connected to the input of the amplifiers 60 and 62 which feed the mixer and the phase detector.

The diodes 134 and 136 and the circuit components connected thereto provide the electronic band switch 58. These circuit components are another pair of diodes 140 and 142, which are oppositely polarized and connected to ground, coupling capacitors 144 and 148 and DC path completing resistors 150, 152 and 156.

When the band A selection voltage indicated as $+V_1$ is applied to the switch 58 from the band selection voltage generator, the diode 142 is biased into its conducting condition as is the diode 134. Whereas, the diodes 140 and 136 are reversed biased. Accordingly, the band B oscillator 56 output is shunted to ground through the capacitor 148 and diode 142, while the band A oscillator output is applied to the output line by way of the forward bias diode 134. Similarly, when the band B selection voltage $-V_2$ is applied to the diodes, the diodes 136 and 140 are forward biased, while the diodes 134 and 142 are reversed biased. Accordingly, only the output of the band B VFO 56 is applied to the output line. Similar diode electronic switches may be used to provide the requisite connections in the band switches 34 and 36 (Fig. 1).

Summarizing, an automatic tuning system embodying the invention is adapted to operate with a radio apparatus having tuned circuits, for example, in the radio frequency amplifiers thereof, and which contains voltage controlled tuning elements such as voltage variable capacitors. These circuits can be arranged in different channels, each channel being provided for a different frequency band. Electronically operated switching means are connected to the channels for selecting the desired band. A variable frequency oscillator is provided for generating mixer injection signals, in the event that the radio apparatus is of the superheterodyne type. Separate variable frequency oscillators may be provided for each band and may be selected by electronic switching means. The variable frequency oscillator is contained in a phase locked-loop together with a phase detector and a pair of generators which supply coarse and fine tuning voltages. These voltages are together applied to tuned circuits in the variable frequency oscillator and in the amplifiers for controlling the frequency thereof. The radio system is tuned by the reference signal which is applied as an input to the phase detector in the loop. The phase detector produces an error signal which is applied to the fine and coarse tuning voltage generators. The coarse tuning voltage generator includes a circuit for generating a staircase voltage which increases in magnitude at a rate which depends upon the difference in frequency between the reference signal frequency and the variable frequency oscillator output frequency. When the variable frequency oscillator output and the reference signal are substantially synchronized, the fine tuning voltage generator provides a tuning voltage which is a function of the varying difference in phase between these signals and locks the variable frequency oscillator to the reference signal. The coarse tuning voltage generator includes a variable frequency clock, specifically a counter, which counts at a rate determined by the component of the phase detector error voltage which is a function of the difference in frequency between the variable frequency oscillator output and the reference signal. This counter controls the generation of a tuning voltage of staircase waveform. When the counter reaches a predetermined count, it produces a control voltage which indicates that the reference signal is out of the tuning range of the tuned circuits in the band which is in use. This control voltage operates the electronic band switching means to select the next band and the coarse tuning process is repeated. In this manner the tuning capability of the system is repeatedly used until the circuits are tuned to the frequency dictated by the reference signal. Since the repeated use or "search", is accomplished electronically, the time to change frequency bands is minimized and manual control is eliminated.

Since an increasing (staircase) voltage is used to perform the coarse tuning, the operation of the circuit is nearly unaffected by temperature, ageing, etc. If an out-of-lock condition occurs, the circuit merely recycles to a new coarse tuning voltage position and relocks.

From the foregoing description, it will be apparent that there has been provided improved automatic tuning apparatus which is used in a receiver. It will be appreciated that the apparatus described is also suitable for use in television and other radio apparatus, including exciters, transmitters and the like.

WHAT WE CLAIM IS:—

1. A circuit arrangement for automatically tuning with the aid of a reference frequency signal, a communications apparatus having at least one tuned circuit, wherein a phase locked frequency control loop includes at least one variable frequency oscillator including said tuned circuit which is

connected with its output to one input of a comparing circuit the other input of which is connected to a source supplying said reference frequency signal, the output of the comparing circuit being connected to a tuning voltage varying in magnitude at a rate determined by the difference in frequency between the reference frequency signal and the variable frequency signal from said oscillator, said tuning voltage generator being connected with its output to said tuned circuit and to the input of the variable frequency oscillator.

2. The circuit arrangement according to claim 1, wherein a plurality of tuned circuits are provided each of which is tunable over a different frequency band, and wherein a frequency band selection generator is connected with its input to the output of the tuning voltage generator, and with its output to electronic frequency band selection switches for switching between said plurality of tuned circuits.

3. The circuit arrangement according to claim 1 or 2, wherein the tuning voltage generator comprises a counter which advances one count for each cycle of said difference in frequency, said counter having connected to its stages an impedance network, a common point of such network being connected to a load across which a staircase voltage is produced which corresponds to said tuning voltage.

4. The circuit arrangement according to claims 2 and 3, wherein the output of the last counter stage is connected to a bistable stage which provides an output voltage which differs for successive counting cycles of the counter, the output of said bistable stage being connected to the frequency band selection generator.

5. The circuit arrangement according to any one of claims 1 to 4, wherein a frequency mixing circuit is connected with one of its inputs to said tuned circuit, while the other mixing circuit input is connected to said variable frequency oscillator which is responsive to said tuning voltage.

6. The circuit arrangement according to any one of claims 1 to 5, wherein the tuned circuit comprises tuning elements the reactance of which varies in accordance with said tuning voltage.

7. The circuit arrangement according to any one of claims 1 to 6, wherein the comparing circuit is a phase detector circuit which produces an error signal supplied to said tuning voltage generator.

8. The circuit arrangement according to any one of claims 2 to 7, wherein a number of variable frequency oscillators is provided which number corresponds to the number of frequency bands.

9. The circuit arrangement according to any one of claims 3 to 8, wherein said impedance network and its counter stages produce said tuning voltage so that it increases stepwise in accordance with the increase in frequency of the voltage at the output of the comparing circuit until such output voltage attains a predetermined value whereupon the tuning voltage decreases abruptly.

10. The circuit arrangement according to any one of claims 1 to 9, comprising a coarse tuning voltage generator and a fine tuning voltage generator, said coarse tuning voltage generator being responsive to the difference in frequency between the said reference frequency signal and the variable frequency signal while the fine tuning voltage generator is responsive to the difference in phase between these signals, and band selection means responsive to the coarse tuning voltage when said frequency difference is greater than a predetermined number of cycles per second.

11. A circuit arrangement for automatically tuning with the aid of a reference frequency signal, a communications apparatus, constructed and arranged substantially as described with reference to the accompanying drawings.

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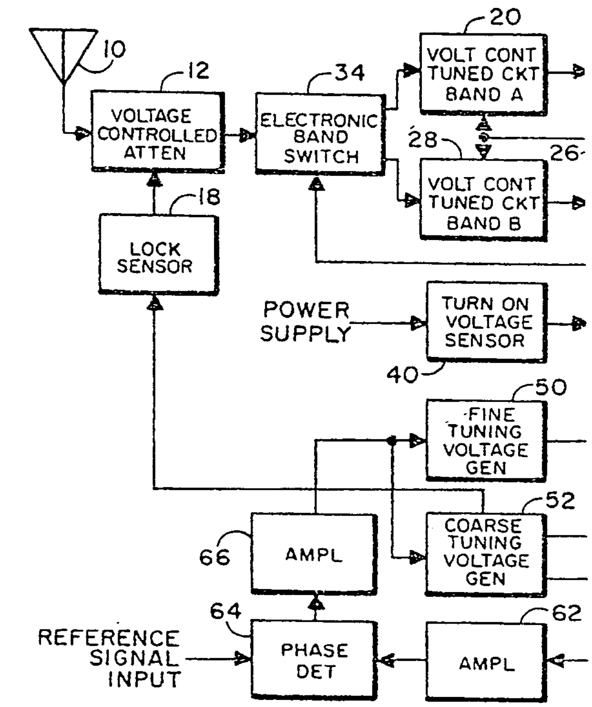
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28
26
VOLT CONT TUNED CKT BAND B
18
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POWER SUPPLY
TURN ON VOLTAGE SENSOR
40
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AMPL
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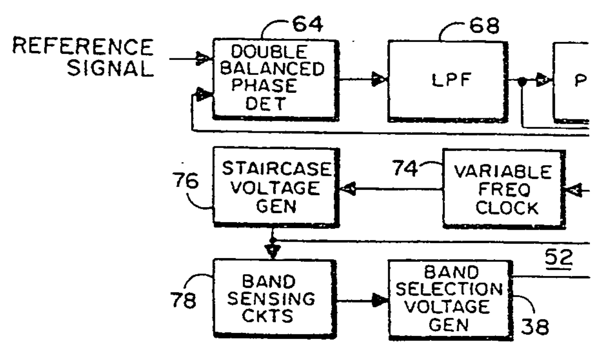
62
AMPL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1190459 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

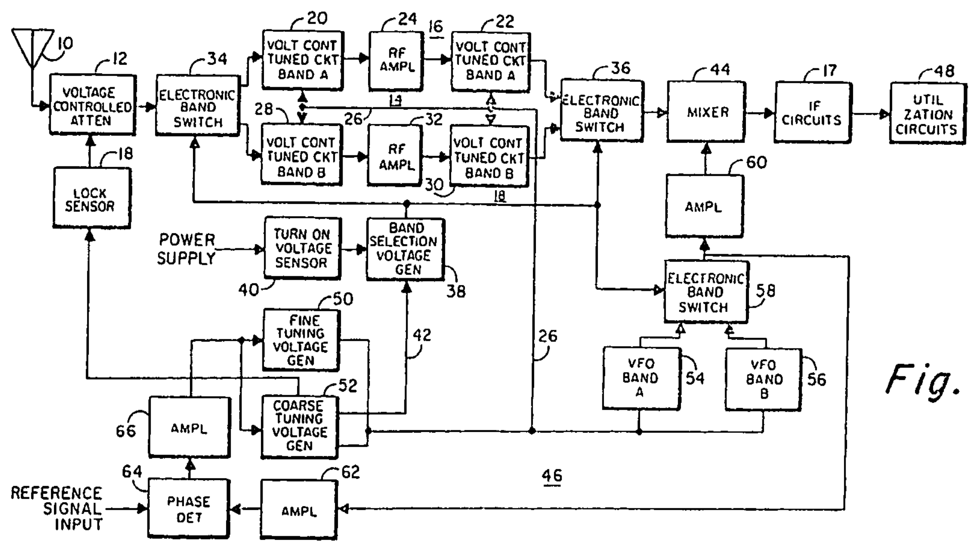


Fig. 1

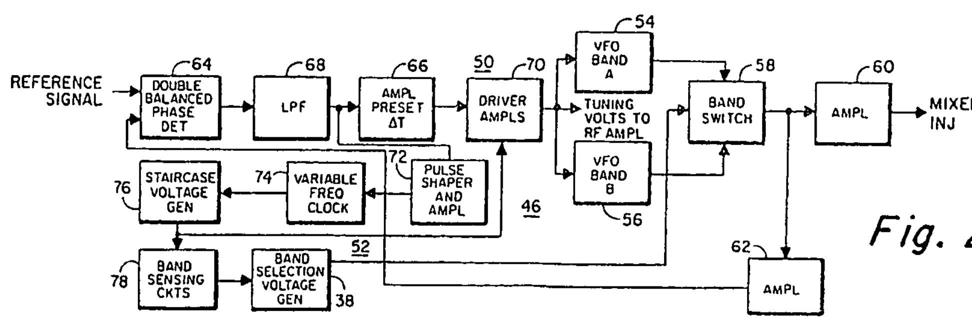
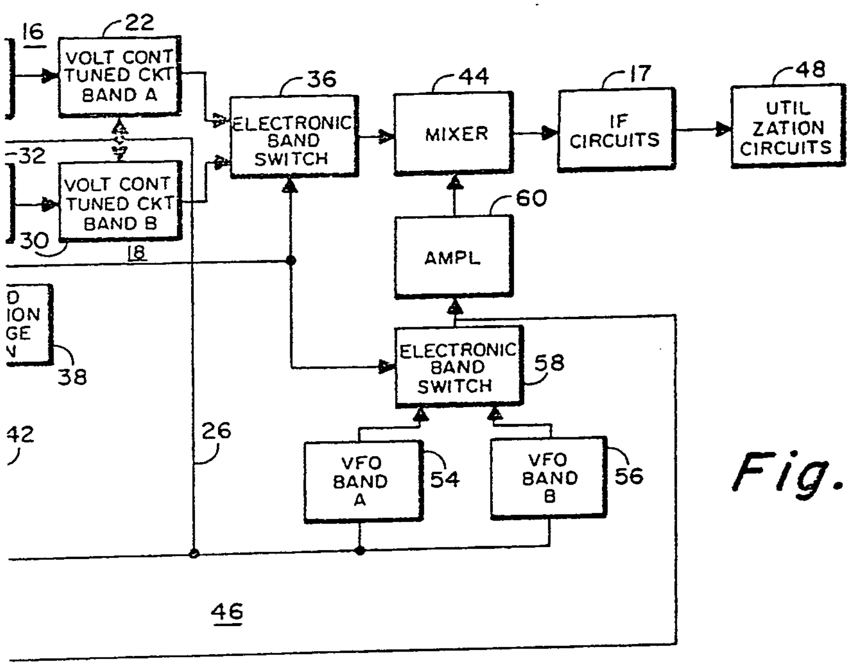


Fig. 2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MIXER
17
IF CIRCUITS
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UTIL ZATION CIRCUITS
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VOLT CONT TUNED CKT BAND B
30
18
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AMPL
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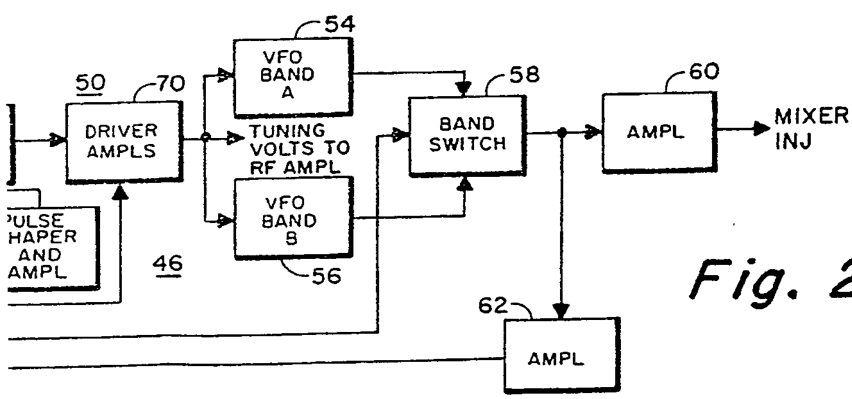
42
26
VFO BAND A
54
VFO BAND B
56
46

Fig. 1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BAND SWITCH
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MIXER INJ
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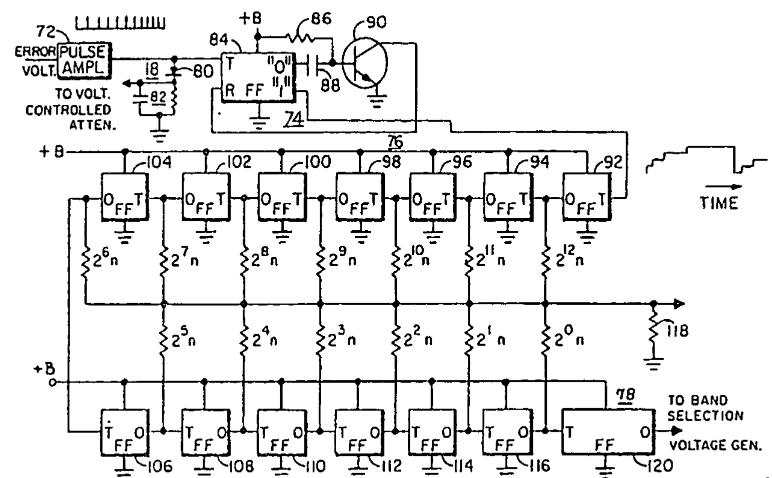
PULSE SHAPER AND AMPL
46
56
62
AMPL

Fig. 2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80
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84
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90
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102
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98
96
94
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2^9n
$2^{10}n$
$2^{11}n$
$2^{12}n$
2^5n
2^4n
2^3n
2^2n
2^1n
2^0n
118
78
T FF O
106
108
110
112
114
116
120
TO BAND SELECTION VOLTAGE GEN.
TIME

Fig. 3

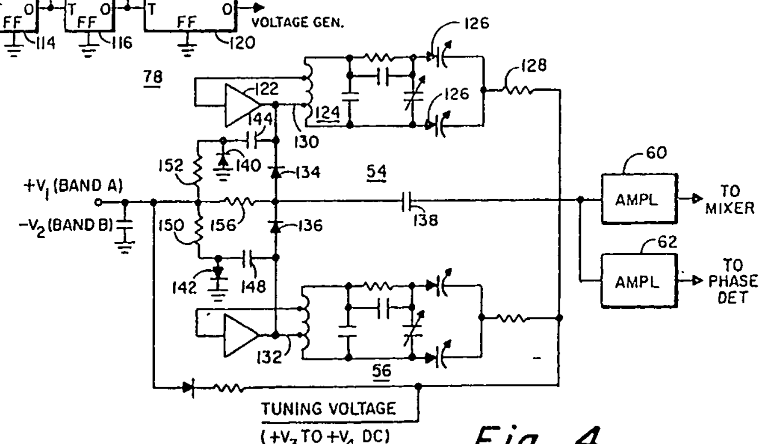

126
128
78
122
144
124
130
140
134
152
54
+V1 (BAND A)
-V2 (BAND B)
150
156
136
138
142
148
132
56
60
AMPL
TO MIXER
62
AMPL
TO PHASE DET
TUNING VOLTAGE
(+V3 TO +V4 DC)

Fig. 4

1190459 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

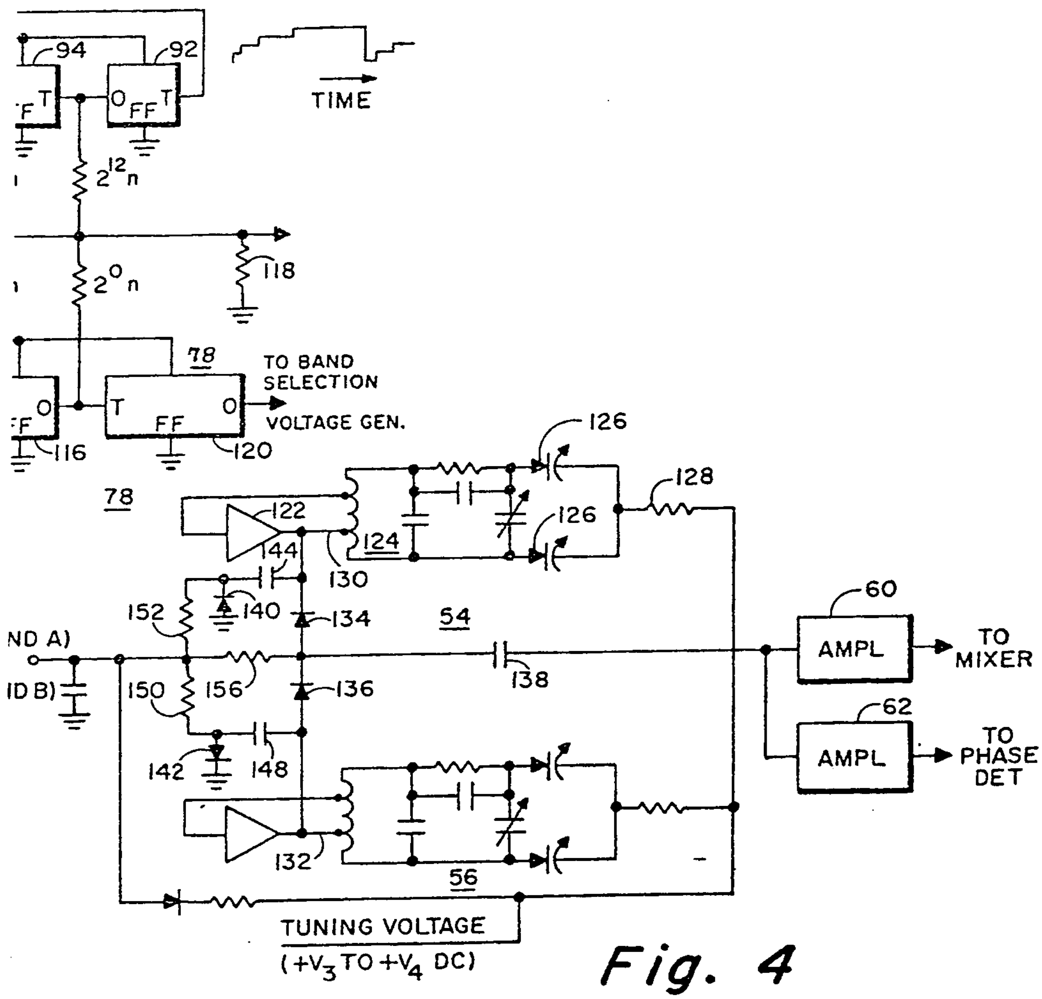
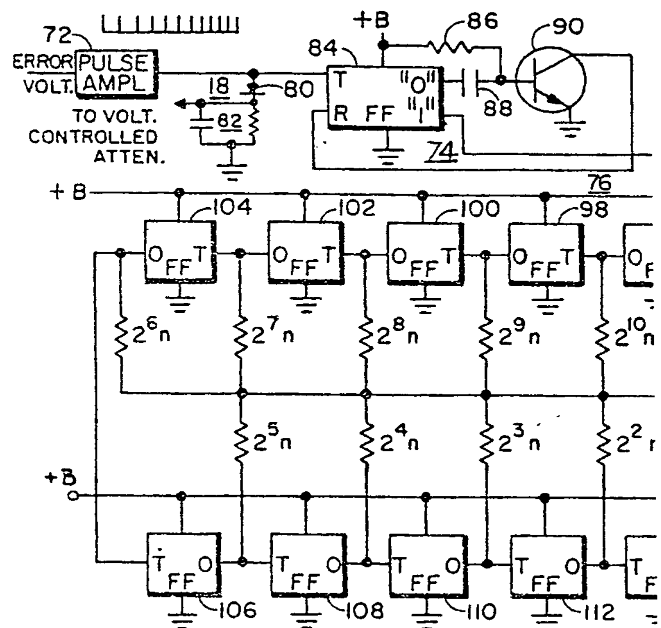


Fig. 4



72
ERROR VOLT.
PULSE AMPL
18
80
TO VOLT. CONTROLLED ATTEN.
82
+B
84
86
90
T
"0"
R FF
"1"
88
74
76
+B
104
102
100
98
+B
106
108
110
112

Fig. 3